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United States
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Soil
Conservation
Service

Phoenix, Arizona

FLOOD PLAIN MANAGEMENT STUDY

for the

KAYENTA COMMUNITY

Navajo County, Arizona



Prepared by the
United States Department of Agriculture
Soil Conservation Service
In cooperation with
Kayenta Chapter, Navajo Nation
Navajo Mountain Soil & Water Conservation District

DECEMBER 1988

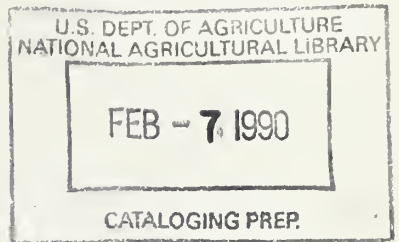
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FLOOD PLAIN MANAGEMENT STUDY
For
KAYENTA
Navajo County, Arizona

INTRODUCTION

Study Request

A resolution was issued by the Kayenta Chapter, Navajo Nation, on October 20, 1985, that directed a request to the Soil Conservation Service (SCS), USDA, to make a flood plain study for an area including and adjacent to the Community of Kayenta. This local unit of government realized the need for information of this nature that would provide management tools to better guide future developments in Kayenta, that would provide more optimum use of flood plain areas, and subsequently, would minimize hazard to life and reduce flood damages.

The Navajo Mountain Soil and Water Conservation District (SWCD) endorsed this request also in October 1985 and recommended that the Soil Conservation Service place this work as a high priority activity.

The Kayenta Planning Board and the Division of Water Resources of the Navajo Nation have endorsed the study. Navajo County Board of Supervisors have also endorsed this effort. The Arizona Department of Water Resources endorsed this study in May 1986 during a coordination meeting with the Soil Conservation Service. They identified no conflicts or duplication of efforts and encouraged the completion of this work.

Local Input

The Kayenta Chapter conducted a public meeting on November 25, 1986 to explain the purposes and uses of this study and to solicit information from the public that could be used in the study. Since that time the Chapter has provided general guidance and information and have assisted in gathering some field data. The Chapter has also paid a major portion of the aerial mapping costs.

Authorities

A plan of work was developed, approved and signed by the sponsors and endorsers by June 1986. In October 1986, the National Headquarters of the Soil Conservation Service authorized the technical assistance and funding to perform this work.

These studies are carried out under Section 6, Public Law 83-566, Watershed Protection and Flood Prevention Act. Rules and regulations contained in 7 CFR621, River Basin Surveys and Investigation, also apply. Executive Order 11988, Flood Plain Management, Section 1, instructs federal agencies to provide leadership to avoid the risk of flood loss, to minimize the impacts of floods on humans, and to restore and preserve the natural and beneficial values served by flood plains. The Unified National Program for Flood Plain Management, Water Resources Council, March 1986 includes provisions to accelerate flood plain management studies and to disseminate information to state and local users.

Technical Procedures

Detailed hydraulic and hydrologic analyses were made of all flow paths within the study area. The flood profiles and cross sections presented in this

report are only for those reaches of channel considered to have sufficient accuracy. Some braided and branching flow paths are shown and should be considered to have less accuracy in their delineation.

Procedures included developing data from field investigations and aerial mapping techniques. A topographic map was made of a major portion of the study area at a scale of one inch equal 200 feet and a contour interval of two feet. The data developed were used in the Corps of Engineers' HEC-2 computer program to calculate water surface profiles (Reference 1) and in the SCS TR-20 Rainfall-Runoff Model (Reference 2) to compute peak flow-frequency relationships.

Reliability of Results

Even though currently accepted detailed technical methods were used throughout most of the study area the results should be considered as best estimates giving varying degrees of accuracy. Those areas of shallow flooding (less than one foot) are not well defined. The nature of the shallow, shifting, ill-defined flow paths on the alluvial plain makes it extremely difficult to define flood boundaries with a high degree of accuracy. These natural complexities are compounded by man-made barriers and diversions such as roads, dikes, fences, buildings, etc. that result in less accurate flood plain delineations. All these conditions require that the flood plain boundaries and flood depth estimates at specific points be interpreted and used with caution.

STUDY AREA DESCRIPTION

Location

This study area is located in northeastern Arizona, in the northern part of Navajo County. It is about 150 miles northeast of Flagstaff and 30 miles south of the Arizona-Utah border. It lies in the vicinity of the junction of US Highways 160 and 163. (Refer to Figure 1.)

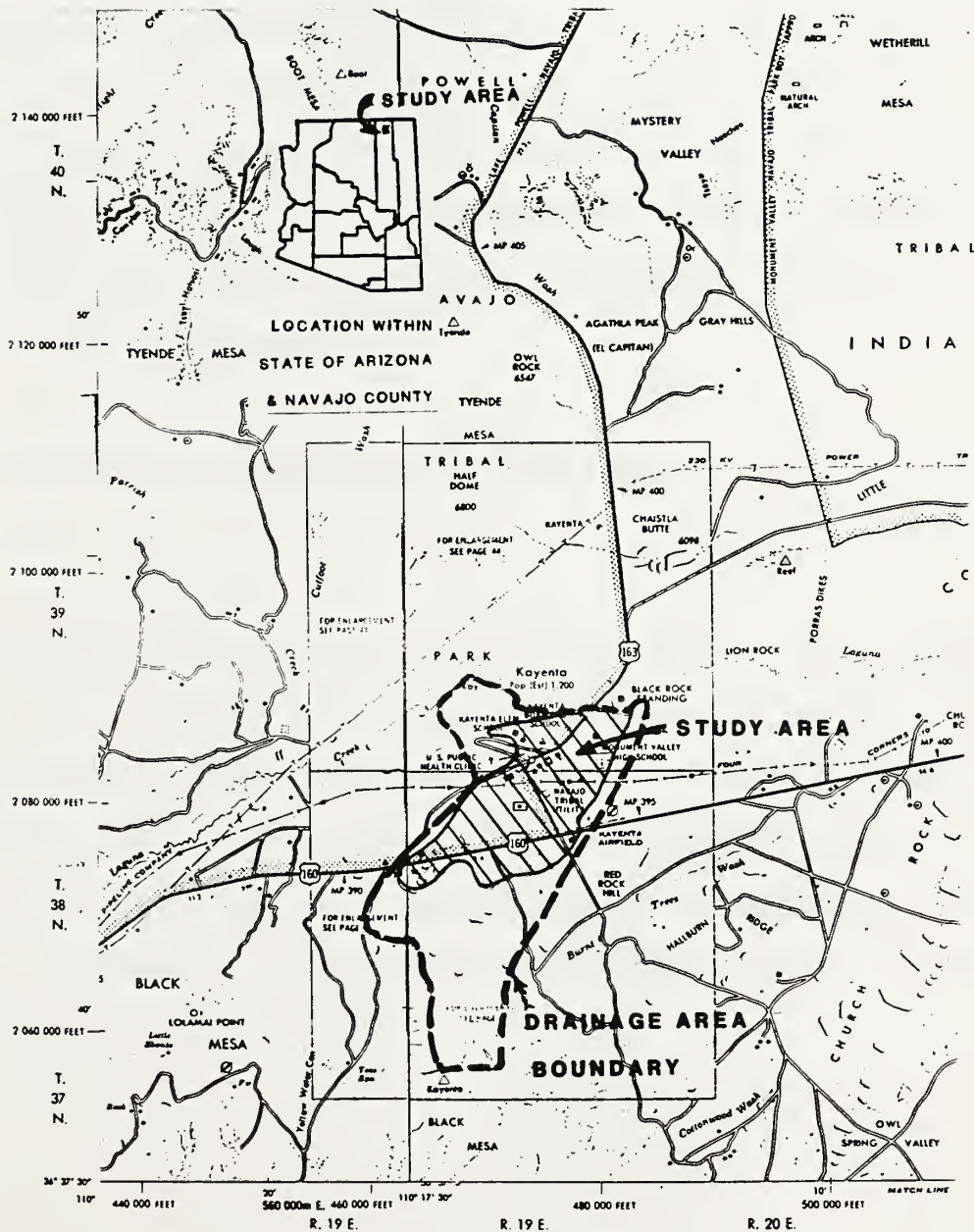


Figure 1
Location Map

The streams draining the watershed area discharge into Laguna Creek which is a tributary to Chinle Wash, all part of the lower San Juan River system. (USGS Hydrologic Unit 14080204-150.)

Settlement History

"Kayenta's beginning as a community can be attributed to the first white settlers in the area, John and Louisa Wetherill, who moved from Oljato to Kayenta and built a home and a trading post in 1909. Because of the many springs in the area, the Indians named the site "To-dan-nas-sha" which translates literally from Navajo as "Flowing Springs". Two years after the Wetherills settled, a post office was established and shortly thereafter work began on a school building. A year later the building was completed and named Marsh Pass School." (Reference 3.)

The 1988 population is approximately 4,050. (Reference 4.)

Climate

Kayenta is surrounded by varied and unusual land features. The most prominent is Black Mesa, to the immediate southwest of the community, rising to an elevation of 8,000 feet above sea level (See photo, Figure 2); Skeleton Mesa to the west; the "Five Toes" sandstone hills of the Kayenta formation to the north; and the volcanic church rock and El Capitan rises to the east and northeast. The community of Kayenta lies on the valley floor at an elevation of about 5,600 feet above sea level.



Figure 2
The Watershed Heads in Black Mesa

The barren desert plateau, affected by the high mountain ranges encircling it contributes to the dry climate of Kayenta. Less than an average of eight inches of precipitation occurs annually. Much of this precipitation falls during the warm summer months when afternoon thunderstorms form occasionally over the strongly heated desert mesas. These local storms, which obtain most of their moisture from the Gulf of Mexico, are usually accompanied by brief, heavy rain showers, often preceded by strong gusty winds and blowing sand. In some years, late summer precipitation may be increased by a dissipating tropical disturbance moving northward from the Gulf of California and the adjacent sections of the Pacific Ocean. These rare storms produce unusually heavy rains, which may persist for more than 24 hours. (Reference 5.) The rains from these two meteorological conditions and moisture sources cause the most severe flooding in the study area.

Kayenta normally receives very little precipitation in the fall, winter and spring. Most of the winter and early spring storms are dry and come from the north or northwest. These storms are often accompanied by strong winds. About seventy percent of the winter precipitation at Kayenta falls as snow. Although amounts are usually small and melt after a few days, accumulations of a depth of more than two feet have been experienced during the colder and wetter winters.

Kayenta has a mild summer climate due to the northerly location and moderately high elevation. Average daily temperatures from the middle of June until the end of August are in the low or middle seventies, varying from the mid fifties near sunrise to the high eighties or low nineties in the afternoon. The area experiences a cold midwinter climate. Early morning minimum temperatures are normally in the high teens or low twenties but during the day warming occurs and the temperature practically is always above freezing. Readings of below zero degrees are recorded in about two out of every three winters. (Reference 5.)

Soil Resources

Over 65 percent of the soils in the watershed area are comprised of Tewa sandy clay loam, Rock outcrop-Torriothents complex and Sheppard-Monue complex.

Tewa sandy clay loam, 1 to 5 percent slopes, makes up about 25 percent of the soils. This deep, well drained soil is on fan terraces and stream terraces. It formed in mixed alluvium derived dominantly from sandstone and shale. Typically, the surface layer is light yellowish brown sandy clay loam 3 inches thick. The subsoil is yellowish brown to brown clay loam and sandy clay loam

about 27 inches thick. The underlying 30 inches of soil is dominantly brown or yellowish brown sandy clay loam. Permeability of this soil is moderately slow and available water capacity is high.

The Rock out crop-Torriorthents complex, 5 to 80 percent slopes, makes up about 21 percent of the soils. This complex is located on hillsides, buttes and mesa escarpments. It formed in colluvium and alluvium derived dominantly from sandstone and shale. The Rock outcrop consists of barren or nearly barren exposures of sandstone. Runoff is very rapid and the hazard of water erosion is high. Torriorthents are very shallow to deep, well drained soils on hillsides and slopes of buttes and mesas. They formed in local alluvium and colluvium from sandstone and shale. These soils have a wide range of characteristics. The surface layer ranges from very cobbly sandy loam to very fine sandy loam. The underlying soil is also highly variable. Permeability of these soils range from slow to rapid and available water capacity is low to high. Runoff varies from slow to rapid.

The Sheppard-Monue complex, 1 to 8 percent slopes, comprises over 18 percent of the soils. This mapping unit is on undulating plateaus. The Sheppard soil is deep and somewhat excessively drained. It formed in eolian deposits derived dominantly from sandstone. Typically, the surface layer is light brown loamy sand two inches thick. The underlying soil to a depth of 60 inches or more is light brown and brown loamy sand and sand. The permeability is rapid and the available water capacity is low. Runoff is slow. The Monue soil is deep and well drained. It formed in eolian deposits over alluvium derived dominantly from sandstone and shale. Typically, the surface layer is brown very fine sandy loam 29 inches thick. The upper 26 inches of the substratum is light brown very fine sandy loam. The lower part to a depth of

60 inches or more is brown and light brown sandy loam. In some areas lenses of gravelly sandy loam occur below 30 inches. The permeability is moderate, available water capacity is high and runoff is slow.

Other soils within the watershed and their proportions include: Monue very fine sandy loam, 1 to 5 percent slopes, 8 percent; Kydestea - Zyme - Tonalea complex, 5 to 50 percent slopes, 7 percent; Mido - Begay complex, 1 to 8 percent slopes, 4 percent; Griffy very fine sandy loam, 1 to 5 percent slopes, 3 percent; Penistaja - Begay complex, 1 to 8 percent slopes, 3 percent; and the remaining 10 percent is made up of Gotha silty clay loam, 0 to 3 percent slopes; Zyme clay loam, 15 to 50 percent slopes; Navajo clay loam, saline, 0 to 3 percent slopes; Ustic Torriorthents, 10 to 35 percent slopes; Querencia clay loam, 0 to 3 percent slopes; Jeddito loamy sand, 0 to 5 percent slopes; Griffy very fine sandy loam, 1 to 5 percent slopes; and Doak fine sandy loam, 1 to 6 percent slopes.

Vegetation and Land Use

The watershed is located in the Colorado and Green River Plateaus major land resource area and in the mixed grass plains and sage brush grassland sub-resource areas. Scattered pinyon-juniper is found in the higher elevations. Following is the approximate distribution of cover types and land use in the watershed:

<u>Cover type and/or land use</u>	<u>Percent of Total Area</u>
Pinyon-Juniper	23
Rangeland	65
Cropland	2
Urban	10
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The rangeland is made up of salt-desert shrub vegetation type with the dominant species consisting of mound salt brush, Russian thistle, Greene rabbitbrush, annual weeds, cheat grass and galleta. Shortgrass vegetation type is located on the broad, level to rolling plains and mesas at a slightly higher elevation. The dominant species are blue grama and galleta.

The urban areas are located in the lower parts of the watershed. Large mobile home and trailer courts are distinguishing developments. The Kayenta Public School complex including school buildings and houses - is also a paramount development. U.S. Public Health Service housing, B.I.A. Kayenta Boarding School, Kayenta Chapter House, Kayenta Field House, various commercial facilities and houses located on the "hill" make up the urban developments.

Drainage Areas and Stream Lengths

The area for which the flood hazard is defined involved the study of eighteen different unnamed channels. Three of these discharge directly into Laguna Creek. Therefore, the study area can be considered to consist of three major subareas with their associated channel systems as follows:

<u>Subarea</u>	<u>Drainage Area (mi²)</u>	<u>Stream Channels</u>	
		<u>Number</u>	<u>Length (Miles)</u>
In Vicinity of Kayenta Primary School and Boarding School (Stream Channel "A")	2.06	2	2.29
Kayenta Public School Com- plex (Monument Valley High School)	.41	1	1.89
Major Washes in Southern Part of the Community (Stream Channels -"B" and "C")	11.40	15	17.97

NATURAL FLOOD PLAIN VALUES

Prime Farmland

The cropland does not meet the criteria of prime farmland due to the lack of water supply. The low annual precipitation makes farming very marginal although the Indian Community has adapted to this condition by special planting and cultivation techniques. The irrigation water supply is unreliable due to timing of runoff in Laguna Creek and problems with keeping the irrigation water diversion and delivery system in operating condition.

About 65 percent of the cropland area lies within the 100-year flood plain.

Land Uses in the 100-Year Flood Plain

The 100-year flood plain, within the study area, inundates about 960 acres. This size of flood will cover about 70 acres of urban land, 110 acres of cropland and 780 acres of rangeland. Refer to the Flood Hazard Map in the back of this report.

Wildlife Resources

The lack of vegetation and, consequently, lack of habitat for wildlife use results in essentially no wildlife permanently residing within the flood plain area. There is some wildlife migration through the area. No threatened or endangered species are known to inhabit this area. There are no permanent wetlands. A reservoir located immediately west of the study area provides a stop over resting place for numerous waterfowl.

Historic and/or Prehistoric Sites

No archeological sites are identified in the flood plain area. There are several hogans, houses, barns, government buildings and businesses lying adjacent to or within the flood plain that may have historical significance. Detailed archeological studies have not been made within the study area.

FLOOD PROBLEMS

Flood History

There are essentially no records of flood events in terms of month and year. Most of the longer term residents recall several "large" floods and judge that at least, on the average, significant flooding occurs two years out of ten.

Area Inundated by the 100-year Flood

Study results show that the 100-year flood can be expected to inundate 960 acres.

Buildings Damaged and Estimated Damage By the 100-Year Flood

Subarea	Number of Buildings Damaged by Type				Total
	Houses/ Apt.	Mobile Homes	Storage Bldg.	Other	
Kayenta Boarding School Area			2		2
Kayenta Public School (Complex Monument Valley High School)	6		5	1	12
Major Washes in south part of Community (Stream Channels "B" and "C")	5	3	1	2	11
Totals	11	3	8	3	25

The damages to buildings and contents by a 100-year flood are estimated to be \$80,900. The average annual damage is estimated to be \$10,200. Other damages such as income losses, transportation damages, emergency costs, etc. were not evaluated in this study.

EXISTING FLOOD PLAIN MANAGEMENT

Regulatory Provisions

The B.I.A., as a federal agency, is directed by Executive Order 11988, Floodplain Management, to assert leadership in reducing flood losses and losses to environmental values served by floodplains and sets forth other important directives.

The Kayenta Planning Board have general responsibilities to guide and promote development within the community. This report is expected to provide a tool for their use in advising development to prevent flood damage.

Structural Efforts

The major work done to protect developments in Kayenta was the installation of an earth channel and dike along the southern edge of the Kayenta Public School complex (Monument Valley High School). This system has functioned well to protect this area. (See photo, Figure 3.)



Figure 3
Kayenta Public School Complex Flood Dike & Channel

A concrete lined channel was also constructed on the southwest edge of the Kayenta Public School complex to intercept local runoff and convey it around to the east edge of the complex. (Refer to photo, Figure 4.)



Figure 4
Kayenta Public School Complex Concrete Flood Channel

Downstream from the above earth channel and dike a flood channel was constructed along the southeast boundary of the sewerage treatment lagoons. Monument Valley Holiday Inn has constructed low dikes on the south and east boundaries of their property.

Various water impoundments have been installed primarily for livestock watering purposes but they have provided incidental flood water storage. Sediment accumulation in these structures has made most of them ineffective for any water storage.

Low dikes have been installed in at least two locations to divert and spread excess water to increase forage for grazing. One dike is located about 3,000 feet to the northwest of the intersection of Highways 160 and 163 and the other is about one mile to the northeast of the highway intersection. These diversion dikes have been silted in and badly eroded to the point where they have little effect. (See photo, Figure 5.)



Figure 5
Dike Installed for Diversion and Spreading Surface Flows

Public Participation

A Public meeting was conducted by the Kayenta Chapter on November 25, 1986 at the Kayenta Chapter House to explain the purpose and uses of this study, receive pertinent information from the public and an opportunity for the public to input flood plain management alternative recommendations.

ALTERNATIVES FOR FLOOD PLAIN MANAGEMENT

Present Condition/No Future Action

Development in the past has been rather slow in the Kayenta community and building locations have been selected deliberately with the major developments on the "hill". Locating buildings on the elevated hill has undoubtedly saved the people much loss from flooding.

In the last decade coal production in Black Mesa has caused a significant increase in population and housing construction. The sites for these buildings were selected with less consideration of flood hazards and, therefore, the potential for damage has increased. Although the damage potential is not high at the present time, in the future if due consideration is not given to flood hazards, risks of damage and loss of life will increase at an accelerated rate.

Land Treatment

There is opportunity to treat the rangeland immediately northwest and south of Highway 160 to decrease runoff. The objective is to increase vegetative ground cover to intercept precipitation, improve infiltration capability of the soil and, to a lesser extent, reduce potential runoff by evaporation and transpiration by the vegetation.

In general the climatic conditions, especially the low precipitation, limit the types of treatment available. The major practice needed is proper grazing use. This practice controls the grazing at an intensity that will maintain or improve the quantity and quality of desirable vegetation. Development of adequate water for livestock and/or wildlife species may be necessary to improve grazing use. The distribution of grazing to the extent feasible will also aid in achieving the proper use.

Deferred grazing for a prescribed period of time or using a practice of planned grazing systems in which two or more grazing units are alternately rested and grazed in a planned sequence for a period of years are effective methods of improving vegetative cover.

Brush management is also apparently needed in the lower elevation areas to restore natural plant community balance. This can be accomplished by mechanical, chemical, or biological means or by prescribed burning. The resulting desirable plants would be expected to provide a larger proportion of ground cover and, subsequently, to decrease surface runoff.

Waterspreading systems can also be installed to divert runoff from the natural channels or gullies by means of dams, dikes or ditches to spread the water over relatively flat areas. This additional water can improve plant growth and, consequently, increase protective ground cover.

(See reference number 6 for a further description of these land treatment practices.)

Preservation and/or Restoration of Natural Values

Application of the above land treatment practices would aid in restoring natural wildlife resources in the flood plain by providing suitable habitat.

It is important to preserve the hogans and older buildings of historic importance. If any construction or alterations of the land surface are considered it is vital that more specific on-site environmental investigations be made to preserve and/or recover any artifacts, buildings or any other important archeological items.

Non Structural Measures

Flood Hazard Information—This report is intended to serve as an important nonstructural measure to reduce flood damages to any future potential developments by directing their location away from the flood hazards. It is intended to be a guide for planning flood prevention measures whether they be structural or nonstructural. This flood hazard information should be made readily available to the public, especially, to those residing in the area and those proposing to build within the area.

Flood Insurance—The Kayenta Chapter may desire to become qualified for the National Flood Insurance Program. This would make specified amounts of flood insurance available under Federal auspices. In return the program requires that the local governments adopt and enforce land use and control measures that will guide land development in flood-prone areas in order to avoid or reduce flood damage. The results of this study can easily be adapted to provide flood insurance data needs.

Flood Plain Regulations—Flood plain use regulations can be imposed to protect those who might consider development in the hazard areas. Zoning to specify the best uses of the area, subdivision regulations to specify provisions to

deal with excess surface runoff, building codes to protect from water damage, dedication of open areas for flood ways, and other regulatory measures should be considered.

Flood Proofing—Flood proofing of existing buildings could provide the most suitable protection. This is especially true when buildings are on alluvial flood plains that have ill defined and changing flow paths. Typically floods depths are shallow, less than one foot, on these areas and flood proofing for these depths is very practical. Existing buildings can be protected by sealing unused openings, applying sealants to walls and floors, constructing fences, wall or berms, lowering streets, etc. New buildings can best be protected by elevating them above the expected flood depths. It is important that careful consideration be given in applying flood proofing either to individual or a group of buildings that no adverse conditions are caused to adjacent or downstream structures due to blocking or diverting flood flows. Significant alterations of direction, amount or velocity of flow may create problems for other locations.

Flood Warning—A flood warning system is not considered very practical because of the short response time between imminent flooding and arrival of the flood. Barriers or warnings should be posted when major flows cross Highway 163.

Relocation—Study results indicate that it may be most feasible to relocate some structures. This alternative may be the best solution to those mobile home units in the Peabody Trailer Court; particularly, those in the 100-year flood plain of the main channel immediately south of this development.

Structural Measures

Since individual efforts can often produce adverse impacts upon adjacent and downstream areas the installation of a more comprehensive system will attain

the most effective control. In this study a more comprehensive system considered the installation of several structural components at five locations where significant damage can be expected. These five areas include (1) the Kayenta Boarding School, (2) the Kayenta Public School Complex, (3) the Navajo Housing Project, (4) the Peabody Trailer Court and (5) the intersection area of Highways 160 and 163. Refer to the map, Figure 6. At each location the evaluation was based upon controlling the 100-year flood. Following is a brief explanation of the findings.

Kayenta Boarding School—Presently, local runoff passes through the school grounds in a shallow depression. There is an existing low capacity pipeline that conveys some runoff through the lower part of the school property. It was decided to consider a pipeline to convey the flood flows through the school, thereby, providing a closed conduct that will give safety to the school occupants. Outlet conditions would require a flood channel to control and convey the floods to a safe discharge point. The costs to install this system are expected to exceed the benefits to such an amount that economic consideration doesn't warrant this action.

Kayenta Public School Complex—When this school complex was constructed a dike and flood channel was installed along the major length of the southern (upstream) edge of the complex. (Refer to photo, Figure 3.) The system was sized such to satisfactorily control what has been determined in this study as the 100-year peak flow. At the head and upstream of this system an older dike (predating 1970) intercepts floodwater and diverts it into this dike/channel system. This study shows that the older dike will be overtopped by the 100-year flood and that it is in a weakened condition that probably will fail by the action of smaller, more frequent floods. Overtopping and/or breaching of this older dike will cause flood damage to the Kayenta Public School Complex

and poses the most risk to life of any of the identified problem areas. This study considered the replacement of this older dike and installing a supplemental dike to tie into the adequate dike/channel. Analysis of cost and benefits indicate questionable economic feasibility but the assessment of other values makes this structure an important consideration.

The Navajo Housing Project—Floodwaters overflowing Highway 163 and along the road drainage ditches are the major sources of damage to this development.

The existing diking along the upstream (southwest) edge of this housing along with the culverts under the entrance road into the development are inadequate to divert and control a 100-year flood thereby allowing significant flooding. This examination considered raising the existing dike, extending the diking upstream to intercept flows coming across Highway 163, installing larger culverts, and constructing a downstream flood channel to a safe outlet point. The evaluation shows the costs to exceed the benefits beyond the need for further economic considerations.

The Peabody Trailer Court—A major wash identified in this study as Stream Channel "C" presents a major threat to this trailer court and, especially, along the southern and southeastern edge of the development. A 100-year flood is expected to inundate about 20 trailer spaces and cause major structural and contents damage to two or three trailers. This study examined the action of (1) relocating the effected structures and (2) construction of a dike to prevent flooding of these properties. Considering that only two or three structures are damaged and that they are readily movable the obvious least cost action is relocation.

The Intersection of Highways 160 and 163—This intersection area is vulnerable from the flood flows from three major flow paths. The existing culvert under Highway 160 is inadequate and the culvert installation under the immediate downstream road is very limited. These channel constrictions can be expected

to contribute to the major overtopping of both highways during a 100-year flood. The overflow will be shallow but rather high velocities. To protect the commercial facilities in this area a dike was considered to extend upstream from Highway 160, to the south, to prevent overflow of this highway and the Holiday Inn parking area. This diking would train the flow through a new battery of culverts relocated to the west in alignment with the existing downstream channel (this would eliminate the old road/culvert constriction). Another dike would extend downstream (northward) from Highway 160, from the culvert outlet to the turn in the existing channel. This diking would prevent overflow of this channel into the intersection area. The infrequency of the overflows and the shallow flooding condition is such that comparison of benefit to cost shows no economic justification for pursuing this action.

In conclusion, after making a preliminary evaluation of the need and opportunity to protect these most hazardous areas by structural methods it appears that from an economic standpoint there is not a sufficient damage potential. Except for the Kayenta Public School Complex, development has taken place to this point, in such a manner, that flooding is mainly a nuisance. It is important to point out the need to use these study results in planning future developments and, especially, to incorporate the results into the comprehensive land use plan for the community. (Reference 7.)



Figure 6
Structural Alternatives Considered

FLOOD HAZARD MAP

A Flood Hazard Map may be found in the packet at the back of this report. The map, on a photo base, shows the 100-year flood area, the locations of many of the cross sections used in the study, the elevations of the 100-year flood at 5 feet intervals up the major streams, and the areas of shallow flooding where the average depth is one foot or less.

There is a significant amount of area shown as shallow flooding with an average depth of one foot or less. The average depth is defined such that the flow cross section area divided by the top width of the cross section is one foot or less. This means that the low point(s) in the flow cross section may exceed one foot (and usually do) but the average depth is less than one foot.

To complement this map refer to the Technical Appendix. This appendix includes peak flow estimates at several key locations, flood profiles for the major streams and representative cross-sections showing the 100-year water surface elevations and resulting depth variations. Some photos are used, at well recognized locations, to show the estimated flow depths expected for the 100-year flood.

GLOSSARY OF TERMS

<u>braided channels</u>	Successive division and rejoining of flows with accompanying islands.
<u>cfs</u>	Cubic feet per second. A unit of water flow.
<u>cross section</u>	A profile of the land surface taken at right angles to the direction of flow; made by measuring the elevation and distance at ground points along the selected line.
<u>drainage area</u>	The area draining into a stream at a given point (also watershed, drainage, catchment basin).
<u>flood</u>	An event where a stream overflows its normal banks.
<u>flood frequency</u>	An expression or measure of how often a flood event of a given size or magnitude should on the average, be equaled or exceeded. For example, a 100-year frequency flood should be equaled or exceeded in size, on the average, only once in 100 years (also recurrence interval, return period).
<u>flood profile</u>	A graph or a longitudinal profile showing the relationship of the water-surface elevation of a flood event to a location along a stream or river.
<u>flood proofing</u>	A combination of structural provisions, changes, or adjustments to properties and structures subject to flooding primarily for the reduction or elimination of flood damages to properties, water and sanitary facilities, structures, and contents of buildings in a flood-hazard area.

<u>flood warning</u>	A community or locally based system consisting of volunteers; rainfall, river and other hydrologic gages; hydrologic models or procedures; a communication network; and a community or local flood coordinator responsible for issuing advance information relative to potential flooding.
<u>hydraulics</u>	The science that treats water in motion.
<u>hydrology</u>	The science that deals with the occurrence and behavior of water in the atmosphere on the ground and underground.
<u>hydrologic unit</u>	An eight digit number coding system established by the U.S. Water Resources Council to identify the hydrologic unit. The first two digits identify the region; the third two digits, the accounting unit; and the fourth two digits, the cataloging unit. The SCS has added a fifth identifying number of three digits to designate a watershed.
<u>mi²</u>	Square miles; a unit of area.
<u>NGVD</u>	National Geodetic Vertical Datum; sea-level datum of 1929, based on leveling surveys of the U.S. Coast and Geodetic Survey.
<u>overland flow</u>	Runoff which flows over the ground surface in a shallow layer as opposed to channelized flow.
<u>peak discharge</u>	The maximum discharge or rate of flow during a flood at a given location.
<u>routing</u>	Determining the changes in a flood wave as it moves downstream through a flood plain or reservoir.

runoff

That portion of precipitation which contributes to flow in a channel or cross the land surface (excess rainfall).

shallow flooding

Areas of unconfined flows over broad, relatively low relief areas such as alluvial plains; intermittent flows in arid regions that have not developed a system of well-defined channels; overland flow in urban areas; and flows collecting in depressions to form ponding areas.

REFERENCES

1. Hydrologic Engineering Center, U.S. Army Corps of Engineers; HEC-2 Water Surface Profiles Computer Program; Users Manual, September, 1982.
2. Soil Conservation Service, USDA; Technical Release No. 20, Computer Program for Project Formulation Hydrology; May 1983 (Draft).
3. Kayenta Chapter, Navajo Nation; Kayenta Chapter Profile, Kayenta, Arizona; Submitted by Albert Bailey, Council Delegate; Edited by Dr. Gerald M. Knowles; September 25, 1983.
4. Arizona Department of Economic Security, Population Statistics Unit; Telephone Discussion, March 4, 1988.
5. Institute of Atmospheric Physics, University of Arizona; Arizona Climate, 1931-1972; William D. Sellers and Richard H. Hill, Editors; Copyright 1974.
6. Soil Conservation Service, USDA; National Handbook of Conservation Practices; As Updated.
7. The Division of Economic Development, Navajo Nation; Kayenta Chapter Comprehensive Land Use Plan; Tulsi Uprety, Director, Economic Planning; Michael Triplett, Economic Development Specialist; Duane Atcitty, Land Use Specialist; June 18, 1986.

REFERENCES

8. National Weather Service, NOAA, USDC; NOAA Atlas No. 2, Precipitation - Frequency Atlas of the Western United States, Volume VIII, Arizona; 1973
9. Soil Conservation Service, USDA; Urban Floodwater Damage Economic Evaluation (URBI) Computer Application Program; January 1982 (Draft).

ELEVATION REFERENCE MARKS

April 1987

MAP IDENTIFICATION NUMBER	SURVEYOR'S IDENTIFICATION NUMBER	DESCRIPTION	ELEVATION
1.	TBM #1	Railroad spike in power pole #4C051; west of Highway 163 near mile past 396; south of inter- section of land fill access road.	5577.37
2.	USGS BM	Standard disk stamped "5613.929 C 31.1933" on sandstone outcrop; 20 feet north of an old road & about 1 ft. higher than old roadway; road is not now in use as the road to Mexican Hat, Utah has been relo- cated east of this site (Highway 163).	5613.929
3.	TBM #3	Railroad spike in power pole #6430 at intersection of Highway 163 & N-S road between Kayenta Trading Post and the Wetherill Inn Motel; NE corner of intersection.	5672.75
4.	TBM #4	Railroad spike in power pole (no pole number); east side of Highway 163, approx. 600 ft. south of the Field House; spike in north face of pole.	5681.89
5.	TBM #5	Railroad spike in power pole in northeast corner of intersection on Highway 160 & Highway 163; spike is in west face of pole.	5716.97
6.	TBM #6	Railroad spike in power pole #280 on south side of Highway 160; approx. 3000 ft. west of Highway 160-Highway 163 intersection.	5768.01
7.	TBM #7	Railroad spike in power pole #B380 on south side of Highway 60; approx. 4400 ft. west of High- way 160-Highway 163 intersection.	5775.74

- | | | | |
|----|---------|--|---------|
| 8. | TBM #10 | Railroad spike in power pole on south side of Highway 160; approx. 2.1 miles west of intersection of Highway 160 & Highway 163; pole is second power pole west of box culvert under Highway 160. | 5833.75 |
| 9. | TBM #8 | Railroad spike in power pole on north side of Old Tuba City Road; east of the intersection with a dirt road east of the old rodeo grounds; approx. 1.1 miles west of Highway 163. | 5748.26 |

TECHNICAL APPENDIX

INVESTIGATIONS AND ANALYSES

Hydraulic and hydrologic studies were performed to derive water surface elevation-frequency estimates. The results were plotted on cross sections and, subsequently used for mapping flood boundaries. These data also were used to estimate flood depths and resulting damages. Field examinations were also made to assess natural flood plain values.

Hydraulic Studies

The basic field survey data were acquired by photogrammetric methods. This work, performed in 1987, provided topographic maps at a scale of 1" = 200' (1:2400) with a contour interval of 2 feet. This mapping also was used to obtain cross section and profile data and plottings.

Roughness coefficients were estimated and mapped in the field. The paths of low flow were also examined and mapped.

Hydraulic computations were made using the U.S. Army Corps of Engineers computer program HEC-2, Water Surface Profiles. (Reference 1.) The output from this analysis provided the basic rating relationship (elevation-discharge) for each cross section.

Hydrologic Studies

The search for data concluded that there are no streamflow data for the streams in the study area. The lack of such directed the use of a computer simulation model. The Soil Conservation Service rainfall-runoff simulation model TR-20 (Reference 2) was used to estimate peak flow-frequency relationships for those streams on the alluvial plain area. The following input data, taken from the listed sources, were developed for use in the computer program:

Input Data

Source

Drainage areas

USGS 7.5 minute quadrangle sheets and the 1:2400 topographic maps developed for this study.

Hydrologic soil-cover complexes
(curve numbers)

Soils mapping data was taken from existing surveys made by the Soil Conservation Service (SCS) on file in the Kayenta Field Office. Supplementary soil mapping was performed in 1987 by SCS personnel to provide the remaining data needs. Range site surveys and mapping was also done by SCS personnel in 1987 to provide cover and land use data.

Time of concentration

These estimates were made using profiles plotted from USGS 7.5 minute quadrangle sheets and approximate hydraulic parameters of channel cross sections. The study results from the hydraulic analyses were used to estimate travel times in the lower part of the watershed.

Precipitation

NOAA Atlas No. 2 Volume VIII-Arizona
(Reference 8.)

Channel flood routing

HEC-2 output ratings of elevation-discharge-area for selected cross sections, taken from the hydraulic study results.

Storm	A storm distribution originally
distribution	developed for New Mexico and
	identified as Type II-75 was used in this
	study. This 24-hour duration storm was
	considered to give the most appropriate
	intensities for time periods less than 24
	hours.

The annual peak flow estimates, resulting from the TR-20 analyses, for selected recurrence intervals and locations are shown in Table 1. These represent the best estimates for present conditions.

Following Table 1 and complementary to the peak flow estimates are (1) floodwater surface profiles for the 100-year flood on the better defined streams; (2) representative cross sections showing the 100-year water surface and (3) photos showing estimated 100-year flood depths at selected locations.

Damage Studies

Damage analyses were made to assess the need and opportunity to take action in reducing the hazards of flooding. Output from the hydraulic and hydrologic studies were used in the URBI computer program (Reference 9) to compute flood depth and damage estimates.

The Kayenta Chapter, with assistance from the SCS, provided building value data and estimates of height from ground to first floor for each building. Ground elevations near each building were determined during the aerial mapping using photogrammetric techniques.

General damage coefficients were taken from data provided by Soil Conservation Service and Corps of Engineers sources. Site-specific data for the study area, normally developed from damage interviews, were not developed.

Inventory of Natural Flood Plain Values

A data search was first made to determine previously identified historic and prehistoric resources in the area. A limited field study was then made to inventory wildlife resources and any historic and archaeology sites. Refer to the narrative description of the report for the findings.

TECHNICAL TABLE

Following is a tabulation of the annual peak flow estimates for selected average recurrence intervals at the specified locations (Refer to Flood Hazard Map):

Table 1-Peak Discharge Estimates

Flooding Source and Location	Drainage Area (mi ²)	Annual Peak Discharge (cfs)			
		10-year	50-year	100-year	500-year
<u>Stream Channel "A"</u>					
Above Boarding School Trib	1.66	1280	2330	2760	3680
@ Outlet into Laguna Creek	2.06	1410	2580	3050	4120
Boarding School Trib to Channel "A" @ Outlet	0.14	120	230	280	420
<u>Stream Channel "B"</u>					
@ Highway 160	1.61	340	790	1030	1680
Approx. 0.4 mile below dam	2.36	330	770	990	1670
@ Highway 163	3.63	410	1060	1390	2490
Above confl. w/channel "C"	4.10	400*	830*	1050*	1420*
@ Outlet into Laguna Creek	11.40	890*	2100*	2720*	4160*
<u>Stream Channel "C"</u>					
@ Highway 160 vicinity of Highway 160-163 intersection	3.51	260	740	1020	1570
Above confl. w/channel "B"	6.65	500	1260	1660	2710
<u>Channel in Kayenta</u>					
<u>Public School Complex</u>					
Overflow of old dike	--	25	340	490	1280
@ Outlet into Laguna Creek	0.41	160	300	420	1130

*Flows effected by overflow of old dike into the Kayenta Public School Complex.

ELEVATION IN FEET (NGVD)

5620

5610

5600

5590

5580

5570

5560

5550

5540

2000 2500 3000 3500 4000 4500 5000 5500

DISTANCE FROM CONFLUENCE WITH LAGUNA CREEK

38

LEGEND

PROFILE SYMBOLS

- 500 Year Flood
- 100 Year Flood
- 50 Year Flood
- 10 Year Flood
- Channel Bottom
- Cross Section Location

6000 6500 7000

KAYENTA FPMS
Navajo County, Arizona
FLOOD PROFILES
STREAM CHANNEL "B"

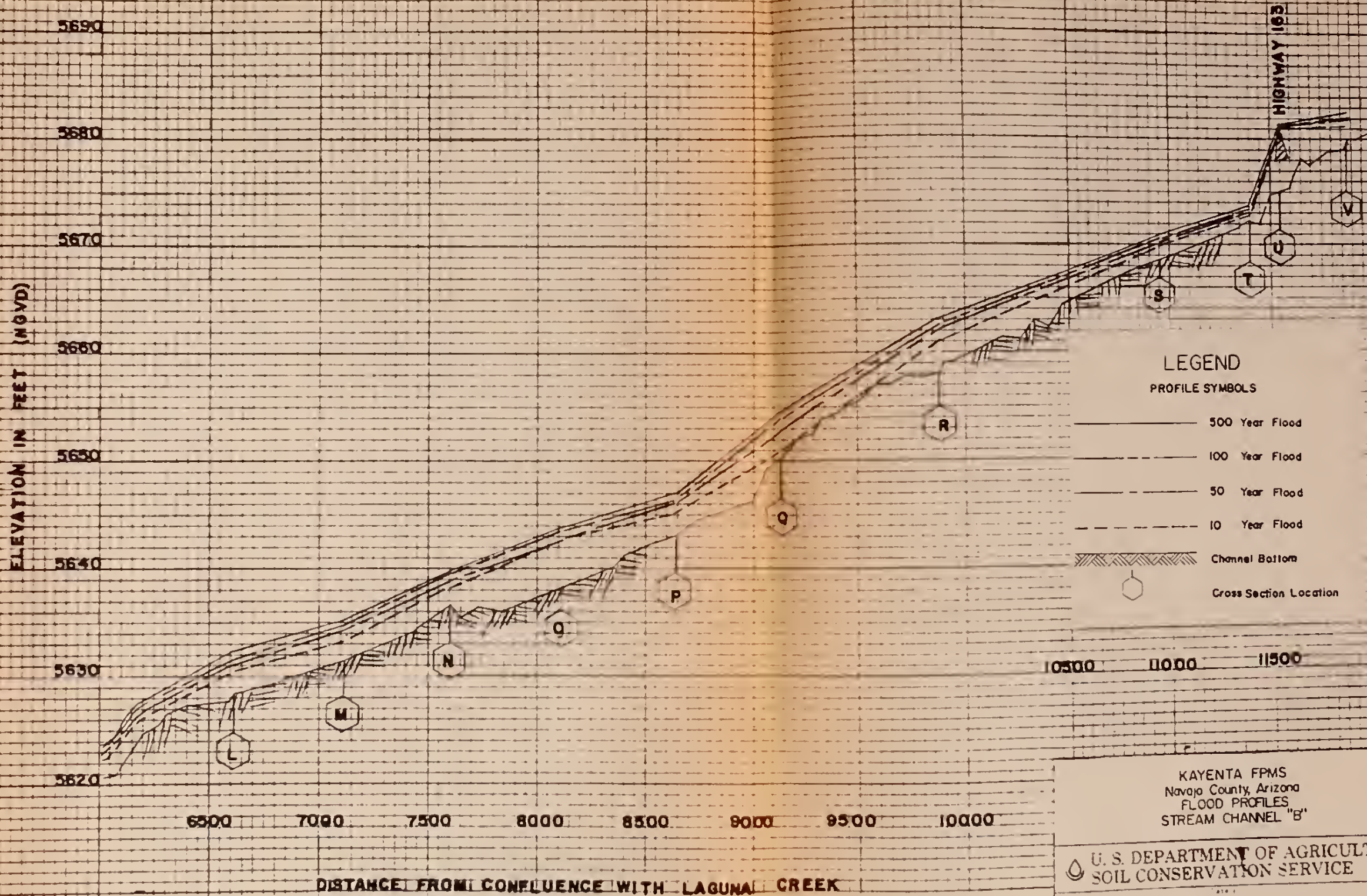
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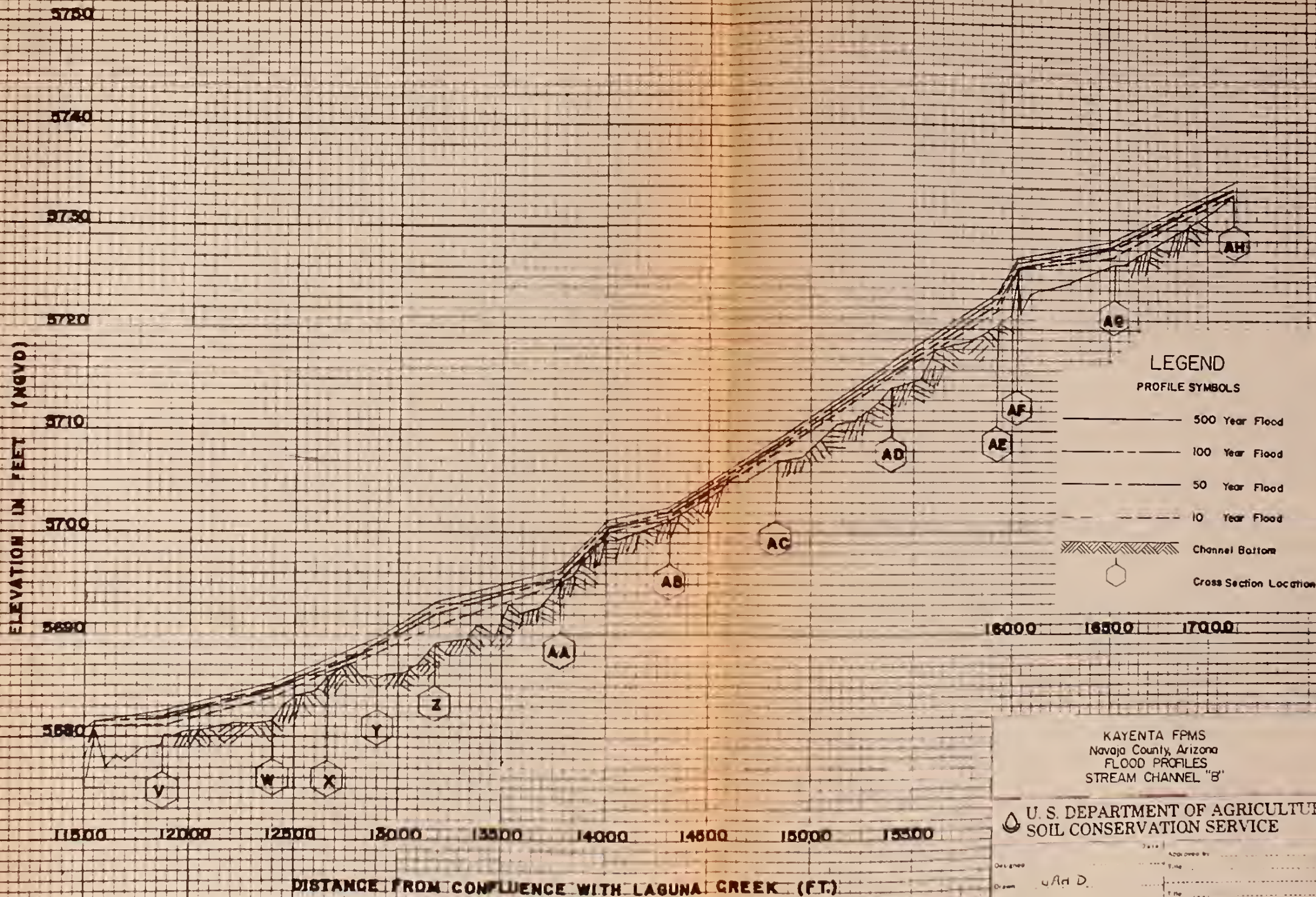
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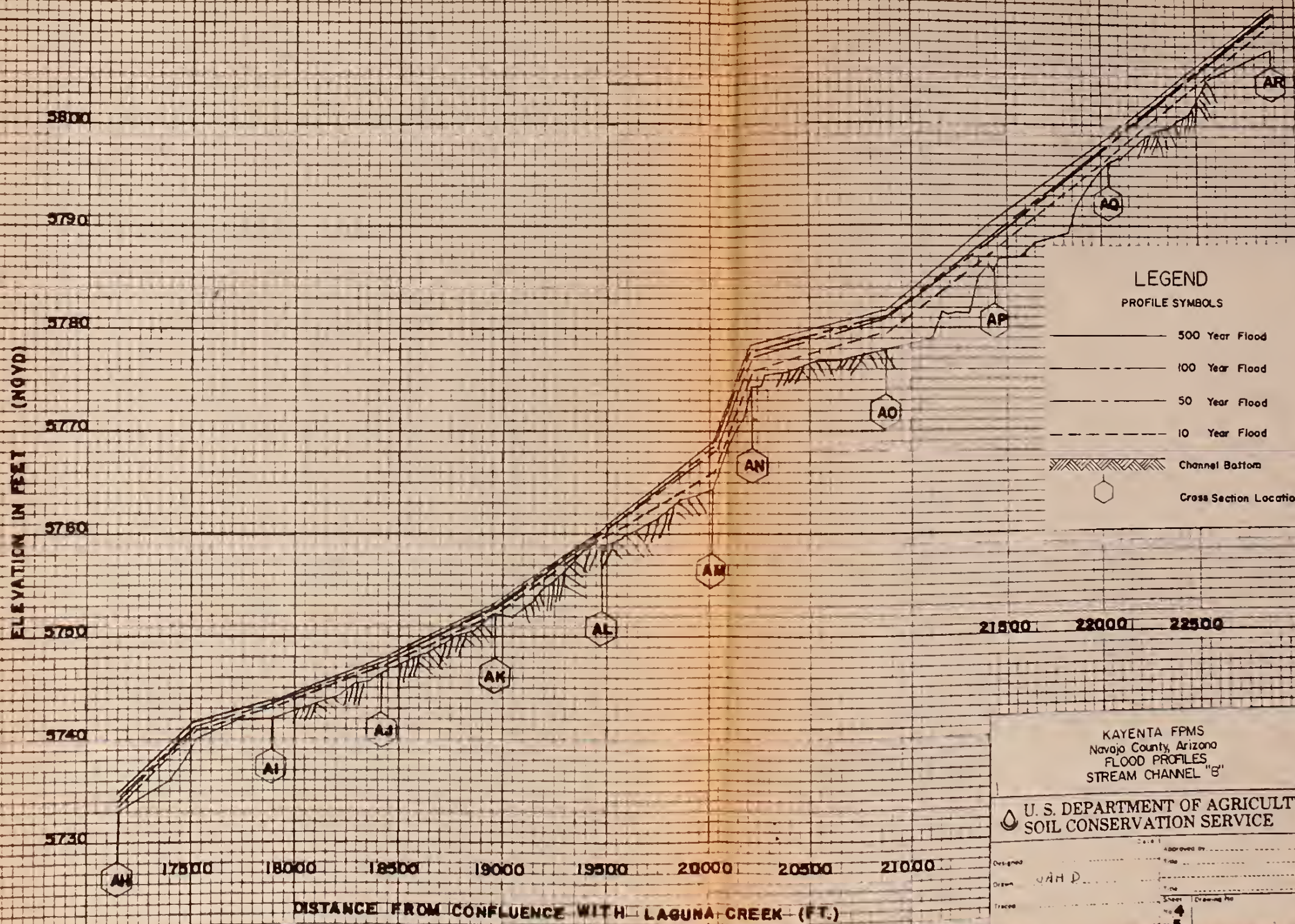
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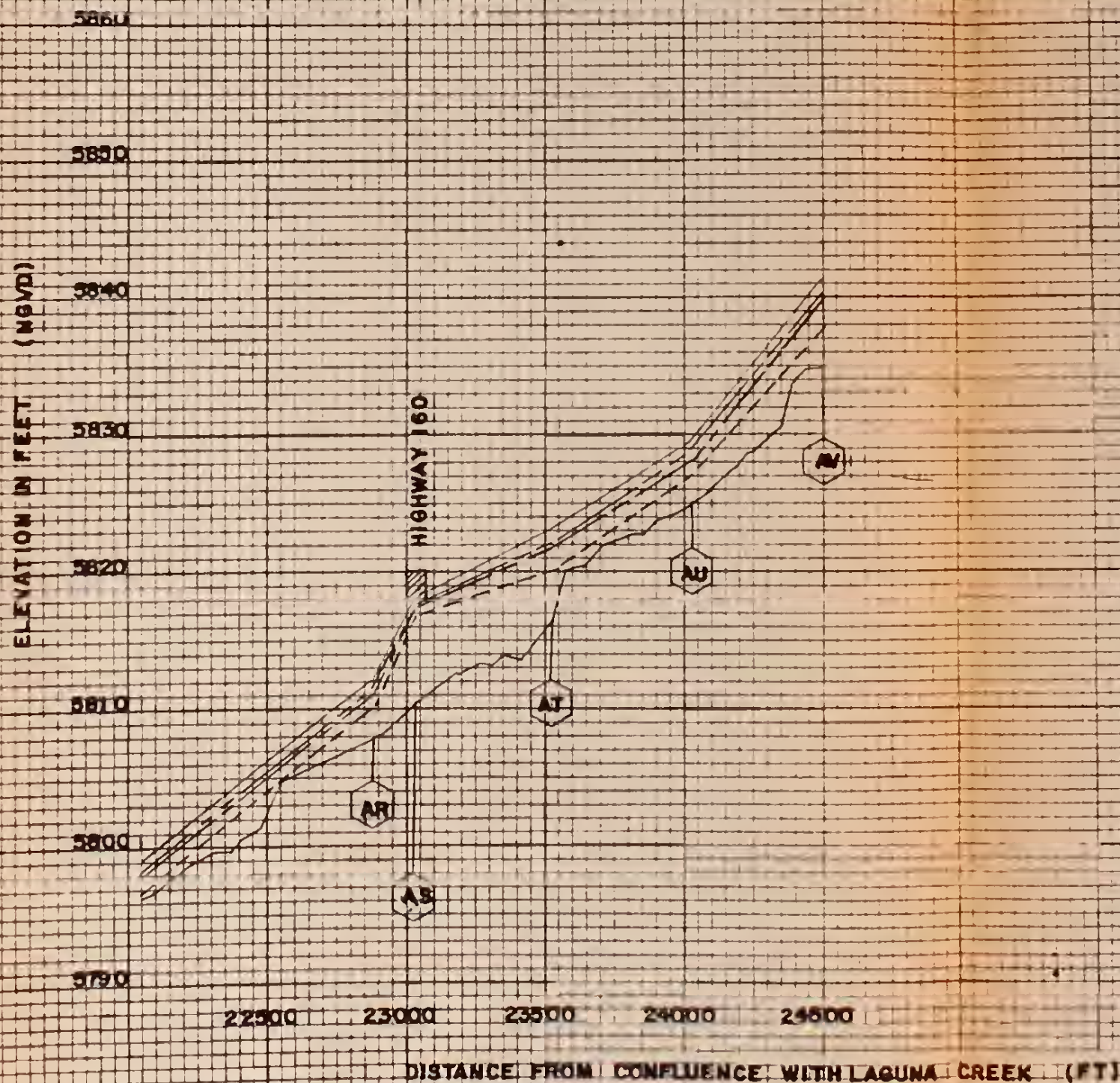


KAYENTA FPMS
 Navajo County, Arizona
 FLOOD PROFILES
 STREAM CHANNEL "B"

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LEGEND

PROFILE SYMBOLS

- 500 Year Flood
- 100 Year Flood
- 50 Year Flood
- 10 Year Flood
- Channel Bottom
- Cross Section Location

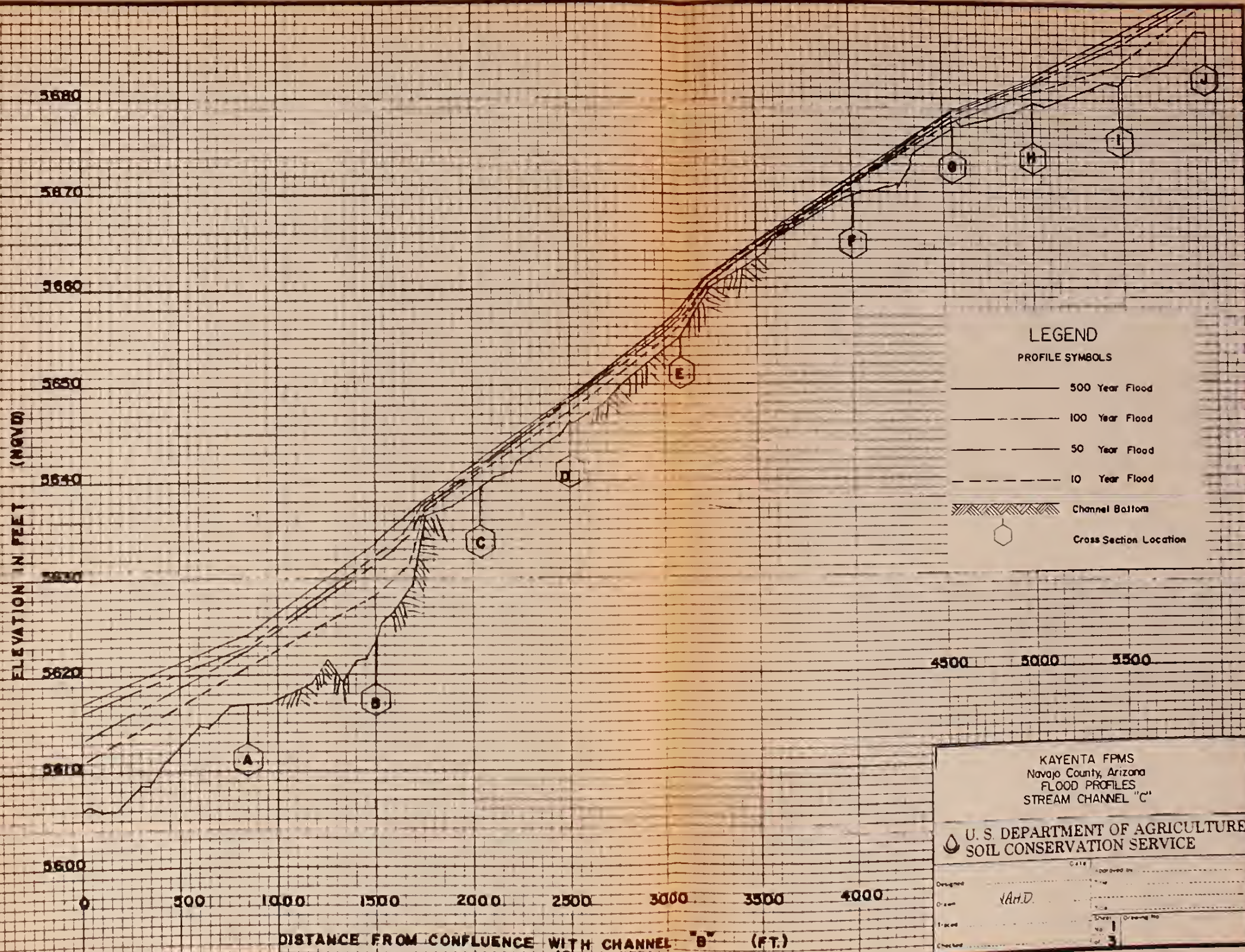
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Navajo County, Arizona
FLOOD PROFILES
STREAM CHANNEL "B"

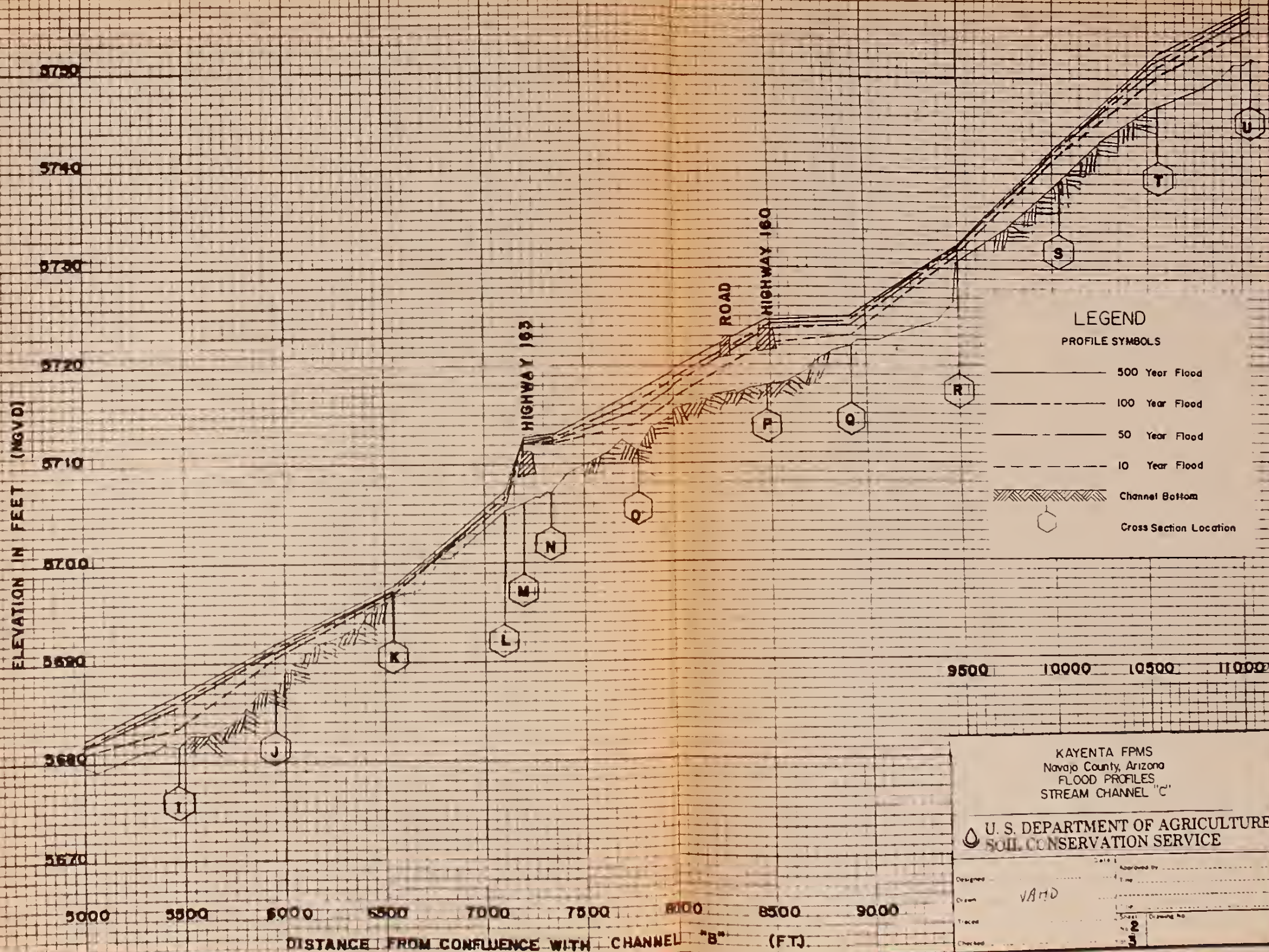
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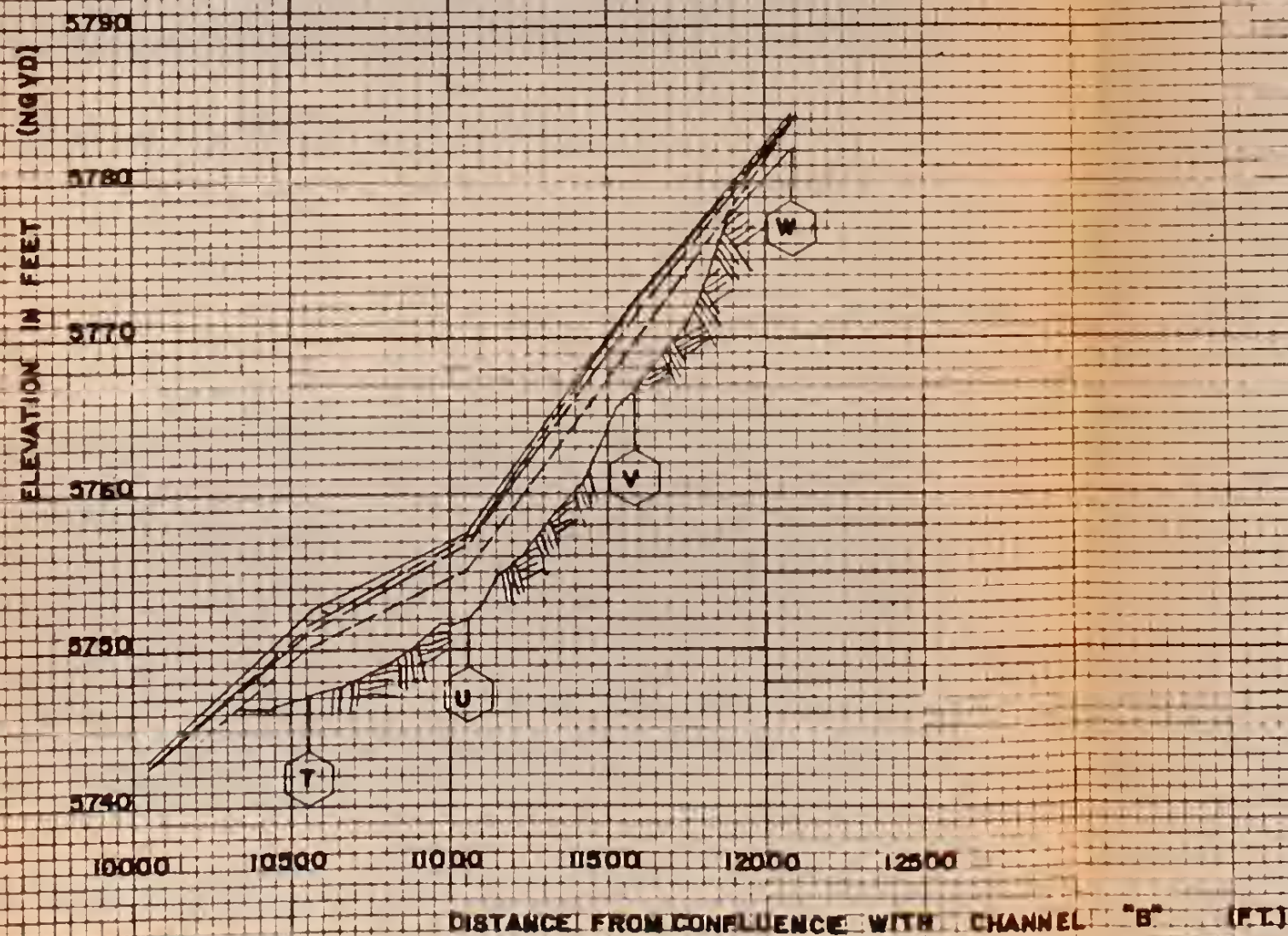
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Signature: JAH

Sheet 5 of 5







LEGEND

PROFILE SYMBOLS

-
- A cross-sectional diagram of a river channel. The channel bottom is represented by a hatched pattern. Above it, four horizontal lines represent different flood levels: the top solid line is labeled '500 Year Flood', the next dashed line is '100 Year Flood', the next solid line is '50 Year Flood', and the bottom dashed line is '10 Year Flood'. A vertical line with a small circle at the top indicates the 'Cross Section Location'.

KAYENTA FPMS
Navajo County, Arizona
FLOOD PROFILES
STREAM CHANNEL "C"

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

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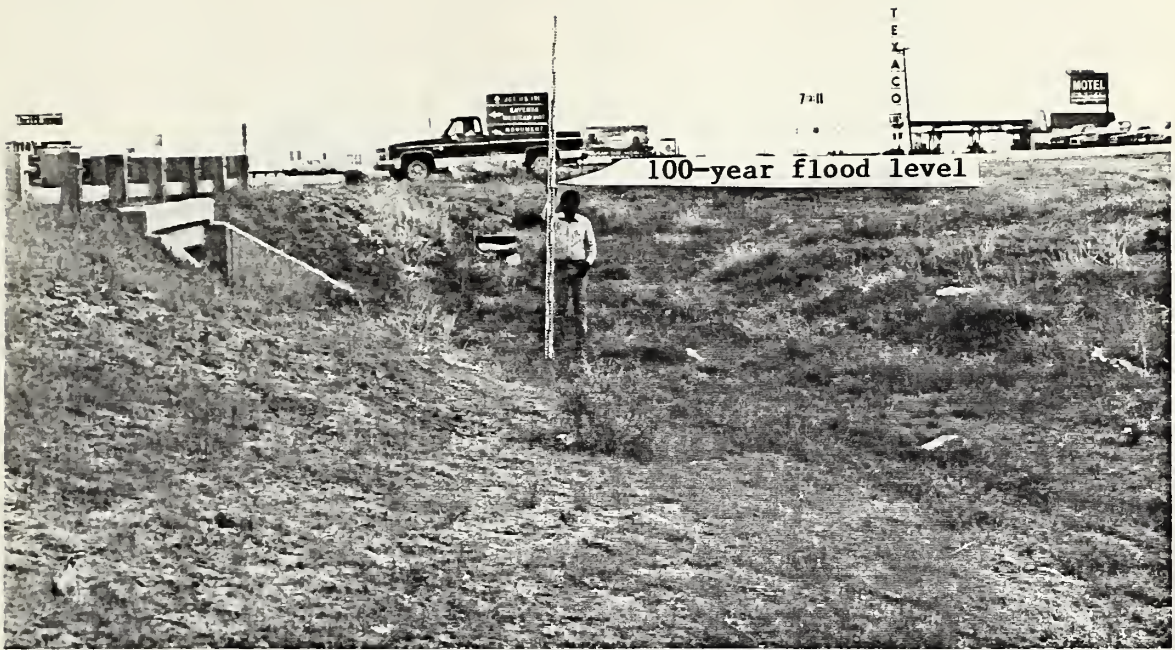


Figure 7
Stream channel "C", at entrance to culvert under Highway 160 near Monument Valley Holiday Inn, near cross section P. Depth, 6.1 ft.



Figure 8
Stream channel "C", at entrance to culverts under Highway 163, north of Highway 160/163 intersection, near cross section N. Depth, 6.1 ft.



Figure 9

Stream channel "C", along Peabody Trailer Court, near cross section J. Depth, 3.1. ft.



Figure 10

Stream channel "B", at entrance to culverts under Highway 163, near Fieldhouse, vicinity of cross section V. Depth, 6.0 ft.

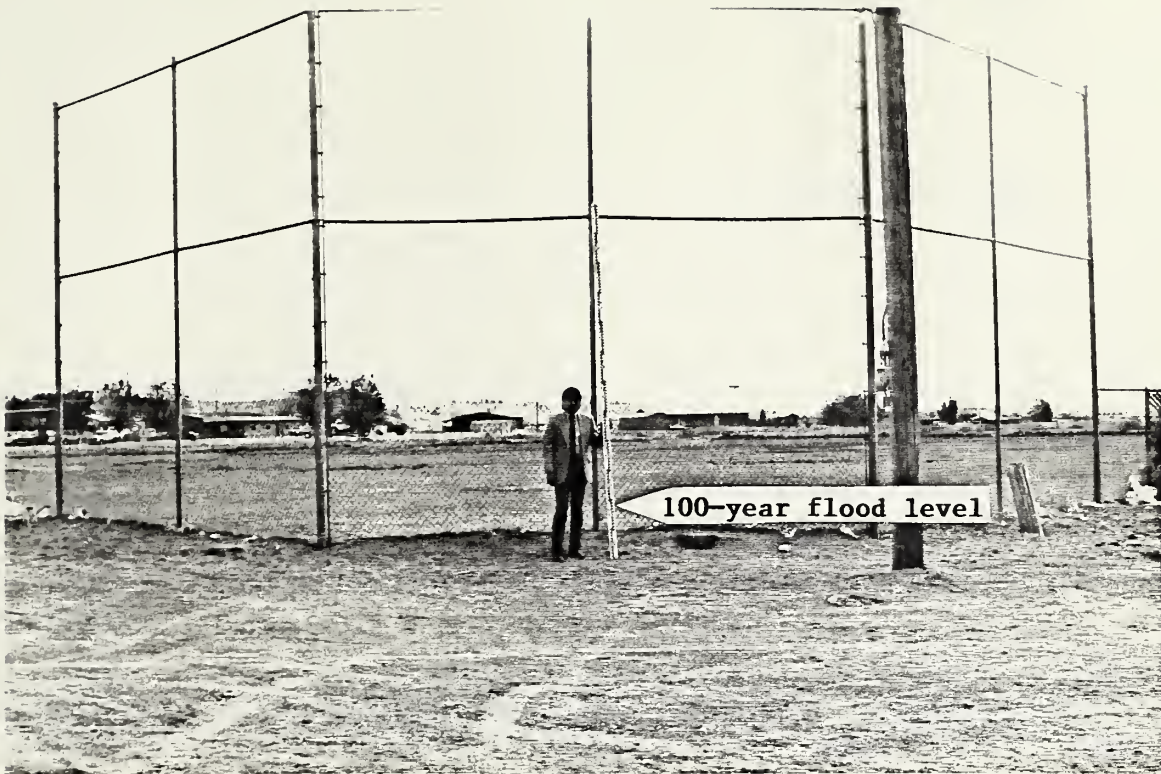


Figure 11
Stream channel "B", at baseball, softball backstop near Fieldhouse, vicinity of cross section S. Depth, 1.7 ft.



Figure 12
Stream channel "B", near head of dike/channel constructed to protect Kayenta Public School Complex, vicinity of cross section Q, Depth, 3.5 ft.

ELEVATION IN FEET (NGVD)

5680

5670

5660

5650

5640

5630

5620

5610

DISTANCE FROM CONFLUENCE WITH LAGUNA CREEK (FT)

LEGEND

PROFILE SYMBOLS

- 500 Year Flood
- 100 Year Flood
- 50 Year Flood
- 10 Year Flood
- Channel Bottom
- Cross Section Location

7000 8000 8500

KAYENTA FPMS
Navajo County, Arizona
FLOOD PROFILES
STREAM CHANNEL "A"

U. S. DEPARTMENT OF AGRICULTURE
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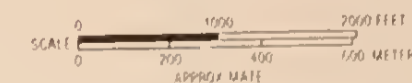


- LEGEND**
- CROSS SECTION
 - 100 YEAR FLOOD ELEVATION
 - INUNDATEO AREA 100 YEAR FLOOD
 - AVERAGE DEPTH EQUAL OR LESS THAN ONE FOOT
 - ELEVATION REFERENCE MARK



**FLOOD HAZARD AREA
KAYENTA
FLOOD PLAIN MANAGEMENT STUDY
NAVAJO COUNTY, ARIZONA**

BY THE
U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
OCTOBER 1988



NOTE: MAP WAS PREPARED TO PROVIDE MINIMUM FLOOD PLAIN MANAGEMENT INFORMATION. IT MAY NOT SHOW ALL AREAS SUBJECT TO FLOODING.

DATE OF PHOTOGRAPHY: APRIL 1987





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December 14, 1988

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Gentlemen:

Enclosed is a copy of the report "Flood Plain Management Study for the Kayenta Community".

This study has been performed under the cooperative flood plain management study programs of the Federal Government. The report presents results to implement programs for reducing existing and future potential flood damages.

Please contact us if there are any questions regarding this work.

Charles R. Adams
State Conservationist



The Soil Conservation Service
is an agency of the
Department of Agriculture

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